CONFIGURABLE FLIGHT SAFETY SYSTEM FOR TRENDS AND STATISTICS ANALYSIS OF AVIONICS SYSTEMS-AN EMBEEDED PERSPECTIVE OF AN EFFICIENT FLIGHT SAFETY TOOL

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Abstract

Federal Aviation Administration (FAA) policy on Flight Operations Quality Assurance (FOQA) indicates that FOQA is a voluntary safety initiative encouraging airline participation in FOQA. It is in the public interest with a necessary requirement that Airlines must document procedures for taking corrective action, when necessary in the interest of safety and airlines must provide FAA with access to aggregate trend data. FAA issues final FOQA rule, in what it called a major step towards reaching its "Safer Skies" goal of cutting the commercial aviation accidents rate by substantially. FOQA programs currently are conducted by airlines, certification authorities and engineering groups of airlines. FOQA is primarily a data collection, processing and analysis system used to improve the various disciplines of flight operations. The Digital Flight Data Recorder (DFDR) onboard provides a wealth of information for rest of the analysis. This information can lead to improvements in aircrew training, maintenance and conduct of safer flight operations. The system can analyze and report the various events, exceedences and reports including statistics for the airline operators.

National Aerospace Laboratories (NAL), Bangalore has designed and developed a software tool called NALFOQA, which is being used by major airlines in the country for flight safety operations and quality assurance activities. Airlines that have started using NALFOQA system have documented a great deal of financial benefit, operational efficiency, reduced insurance premium, better safety levels as well as improved training and safety of operations. NALFOQA focuses on the criticality issues to expose the hidden aspects of flight safety part of aircraft information management system in terms of its design criticality, flight operational features with justified usage, quality assurance facts and figures as focused on the recorded data and a voluminous types of reports, charts, graphs and statistical information for very effective flight operations with professionally documented results.

The paper presents the methodology of data processing for various fleet of aircrafts with controlled parameter limits and conditions with logical envelops bounded by derived mathematical approaches for the trends and statistics of various systems and components of aircraft using NALFOQA. The quality assurance in terms of flight operations and avionics system diagnostics is realized by flight data analysis, which is the heart of the system. This Paper also presents about the flight safety issues of the aviation industry in particular to the quality assurance areas of aviation using the techniques of data processing and database management for the history of each and every aircraft including the engineering database.

1. Introduction

DFDR's / Solid State Flight Data Recorders (SSFDR's) are being successfully used on civil aircraft for decades. Their proven survival strategy of deploying away from the aircraft and hence the crash site, allows for quick location and economical recovery of recorder information, particularly in marine incidents, where the floating recorders can readily be retrieved from the surface of the ocean. Changes in the needs of accident investigators, and in aircraft use, application, performance monitoring, routing, and avionics have resulted in the current initiatives underway to revise aviation recorder standards, their quality and data analysis. Vast majority of information gained by FOQA cannot be found in any other way as it provides objective and "actionable" data for all equipped flights.

FOQA serves as a catalyst for voluntary information exchanges in a way that the periodic line checks conducted by check airmen cannot provide the same level of insight into daily operations as the continuous monitoring of FOQA data. A program for obtaining and analyzing data recorded in flight (operations) to improve flight-crew performance, air carrier training programs and operating procedures, Air Traffic Control (ATC) procedures, airport maintenance and design, aircraft operations and design. In practice, a FOQA program is a subset of a total in- flight data system that includes engine maintenance and aircraft-systems monitoring. FOQA is, however, separately managed, has separate data requirements, specific hardware and software requirements (some measurement-system hardware and recording-system hardware may be shared), and is subject to a separate, more secure management process.

FOQA program provides meaningful, manageable information that can be used to facilitate sound decision- making for both day-to-day operations and long-term planning, Flight Operations, Maintenance and Engineering, Pilot training and Safety. This paper provides information on the national aviation system to allow the assessment of the safety, which in turn helps in increase of efficiency of the operational use of the airspace, also generates statistical data that can be used to evaluate performance of airlines with new programs.

1.1 Role of FOQA in Airlines operation/ Civil Aviation

The reason why the aircraft accident rate has stayed fairly flat since the mid-70' has caused many to speculate as to why. First of all, - is it at an acceptable level? Or is "Zero Accidents" an attainable goal to strive for. If we look back the history of civil aviation operations, there has been a remarkable developments in terms of technology change from 1970's to current day and at the same time the airspace operations also has increased tremendously with various kinds of airplanes and systems. Present day concepts of Integrated Aircraft Monitoring Systems (IAMS) plays a very important role in monitoring and processing of various levels of aircraft data online and offline. FAA Advisory Circular FAA AC 120-82 [7] provides the base for the FOQA functionalities and responsibilities in terms of operation and importance.

1.2 Embedded Perspective of FOQA – Integrated Monitoring Systems

Close monitoring of aircraft flight operations and systems has made continuous refinement of reliable designs and increased performance. Enabling this operational monitoring has been the continual development of even more sophisticated data recording analysis with growing capabilities to handle huge amount of raw data. Feedback into engineering and maintenance processes and into crew training has raised safety levels. Coupled with accident investigation information, operational data extracted from the Flight Data Recorder have made it possible to refine the air transport operation to very high standards of efficiency, while at the same time, reducing accident risk exposure. The FOQA developed from flight safety foundation (FSF) studies, is being adopted by many airlines throughout the world as an internal system of operations monitoring.

FOQA data can reveal

- If an airline's trends are out of the norm
- If anomaly is an isolated occurrence or one that has been previously detected by another carrier who may have already developed a solution.
- If occurrence is a significant event that requires prompt decision- making and actions when combined with historical data
- Allow the confirmation of problem areas identified by flight crews through voluntary safety reporting programs
- Flight performance/training
- Airline safety improvement
- Human factors study
- Operational procedures review.

1.3. Growing steps of configurable NALFOQA towards Aircraft Integrated Management System concept

NALFOQA [1] is being used at airlines for variety of aircrafts from Boeing and Airbus industry covering 64, 128,256 and 384 words per second format. It has proved to be one of the best tools for aircraft integrated data monitoring and analysis system. The software is designed to be an universal

tool which can be easily configured for any aircraft with the characteristics of aircraft is known in terms of the Digital Flight Data Recorder (DFDR) / Solid State Flight Data Recorder (SSFDR) parameter specifications. The tool can be used as

- Aircraft integrated data monitoring and analysis system
- Incident / Accident analysis and report generation tool
- Aircraft performance monitoring system
- Pilots operations and quality monitoring and evaluation system
- Airlines statistics management system
- Post flight analysis and councelling tool
- Airlines efficiency management system
- Operations and quality control and management system

Incident:

NALFOQA software can be used for incident analysis in an efficient way. Annex 13 to the International Civil Aviation organization (ICAO) Chicago Convention defines an incident as an event linked to the operation of an aircraft, which is different from an accident and jeopardized or could jeopardize the safety of the operation. It defines a serious incident as an incident whose circumstances indicate that an accident almost happened, and clarifies that the difference between an accident and a serious incident lies merely in the final outcome. Also an incident [7] defines as an occurrence, other than accident, associated with the operation of an aircraft, which affects or could affect the safety of operation. Indeed Incident analysis is a major step, which will un-earth many issues of maintenance, operations and crew performance. Many practical examples reveal that if the incident analysis is carried out in systematic un-biased methodology, the operations efficiency and quality assurance objectives will definitely be fulfilled. This process enhances the systems efficiency in terms of maintainability, maintenance, preventive actions and reliability of the system.

Accident:

Accident analysis is more legal oriented where lot of activity need to be produced for verification and validation including the process itself in some cases. The data is looked at in a very critical manner to the bit level in case of corrupted/damaged data. NALFOQA can be used for this purpose in a sector analysis mode with bit wise data extraction capability as an optional analysis.

2.0 NAL Flight Operation Quality Assurance (NALFOQA) software

NALFOQA is a window-based software with database support. Database forms the base for all the trend analysis system with lot of information processed and archived. The software needs to be equipped / configured for the aircraft behavior in terms of the parameter details, phase limits and event limits. The Sequence of operations to be carried out is

- Aircraft / Configuration creation
- Parameter Configuration
- Phase Configuration
- Event Configuration
- Airlines fleet cycle configuration

2.1 Aircraft Configuration

Any new aircraft or a different configuration of the old aircraft needs to be configured into the NALFOQA for further use and reference.

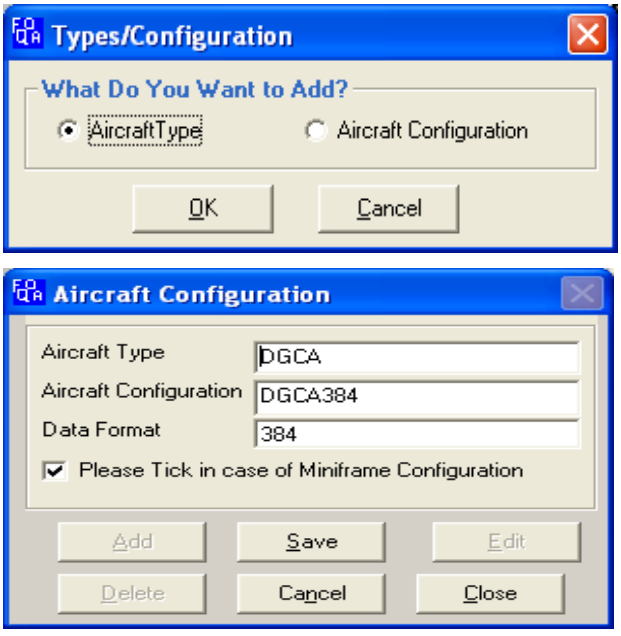


Figure 1 Aircraft Configuration in NALFOQA

Aircraft and its configuration form the basis for all the subsequent operations of incident / accident / operations analysis as part of the Aircraft Information Management System (AIMS). NALFOQA has the provision to have database facilities for the configuration [2]. The configuration menu of NALFOQA is as shown in Figure 1. NALFOQA can be used to configure any aircraft and start using it for analysis and has no limitations for decoding and analysis. The configuration depends on number of frames, sub-frames, mini-frames and format of recording like 64, 128, 256, 384 words/sec etc. This will be derived from the Aircraft Maintenance Manuals (AMM)[3][4] of respective aircraft.

1.3 Parameter Configuration

Digital Flight Data Recorder records data from various sub-systems of the aircraft. The parameters so recorded falls into different types of signals, varied operating range, different resolution, varying recording bit occupancy for each parameter and the same signature need to be fed to the NALFOQA to understand the aircraft parameters for further analysis. The configuration of parameters in NALFOQA is exercised with special security password to protect the integrity of the database. The parameter configuration user interface of NALFOQA is shown in Figure 2. Synchronization words (SYNC) are the main known pattern words in each sub-frame to identify the state of the sub frame.

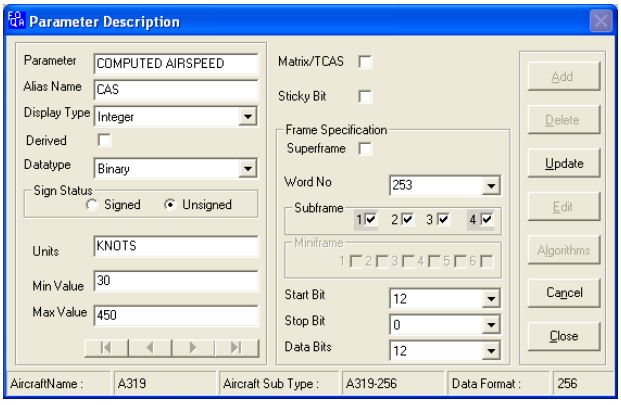


Figure 2 Parameter Configurations in NALFOQA

The Digital Flight Data Recorder / Solid State Digital Flight Data Recorder parameter decoding is done after the parameter information is configured into NALFOQA. The decoding system with the digital display of continuous flight data will be displayed for incident/accident/operations analysis to the second level resolution.

1.4 Phase Configuration

To investigate the incident for specific time of flight in terms of flight phases, the NALFOQA need to be configured for the cutting limits of various phases of the specific aircraft family. The investigation will be carried out with reference to the configured phases only. The phase configuration user interface of NALFOQA is shown in Figure 3.

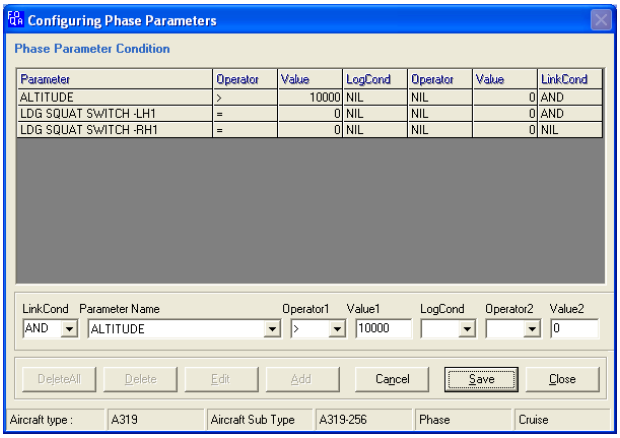


Figure 3 Phase Configurations in NALFOQA

1.5 Event Configuration

An event is an exceedence of a parameter or a set of parameters constituting the functionality of the aircraft scenario in specified conditions deviating the norms. Each event has a set of limits to be checked during the event detection process. The Event configuration parameters are defined based on the dynamics of the aircraft and its behavior. The event configuration window is as shown in Figure 4.

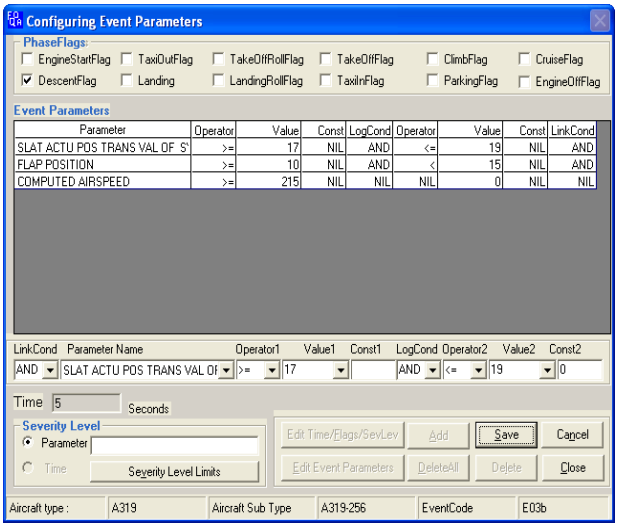


Figure 4 Event Configuration system of NALFOQA

Parameter, event and phase configuration of NALFOQA completes the configuration activity and is ready for incident/accident analysis activity.

1.6 Data Processing

The aircraft downloaded data [5] directly from the DFDR is fed to NALFOQA for data processing and analysis. The data processing facility and its output as consolidated result of NALFOQA is as shown in Figure 5.

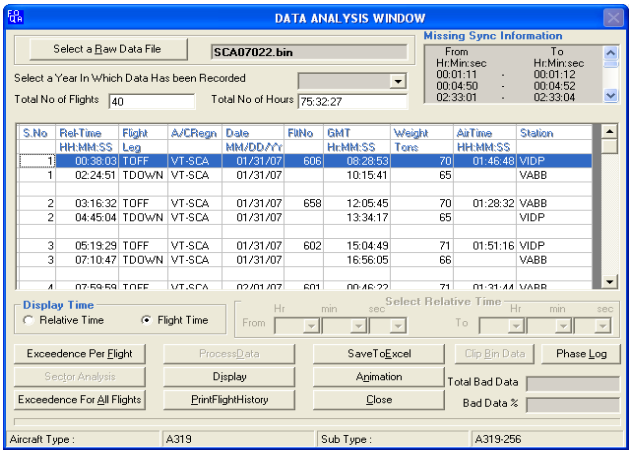


Figure 5 NALFOQA Aircraft Integrated Data Processing System

The first level of analysis reports the basic information, which will aid for further analysis. Event detection and monitoring is the most important activity of the analysis system with the event monitoring report for the full length of flight data or for each sector separately. A typical event report is as shown in Figure 6.

Each event in the event monitoring report in Figure 6 is reviewed and checked for its reality and the severity-persistence in terms of the time and limit value. The entire processed data is stored into the master database for all statistical report generation.

1.7 Event Monitoring, detection and analysis

Crucial phase of FOQA is the event monitoring and analysis. NALFOQA provides an efficient methodology for the event analysis as shown in Figure 6.

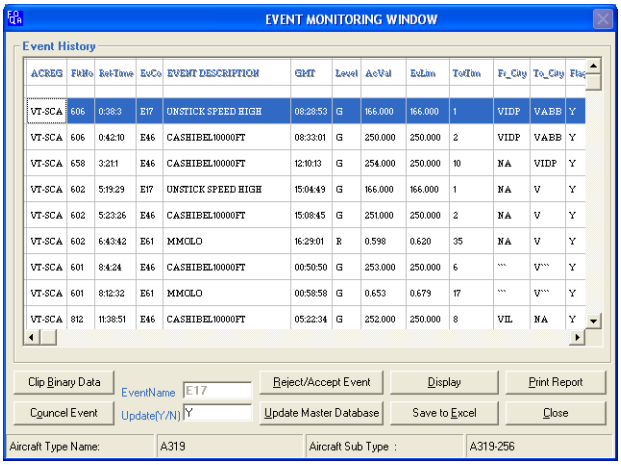
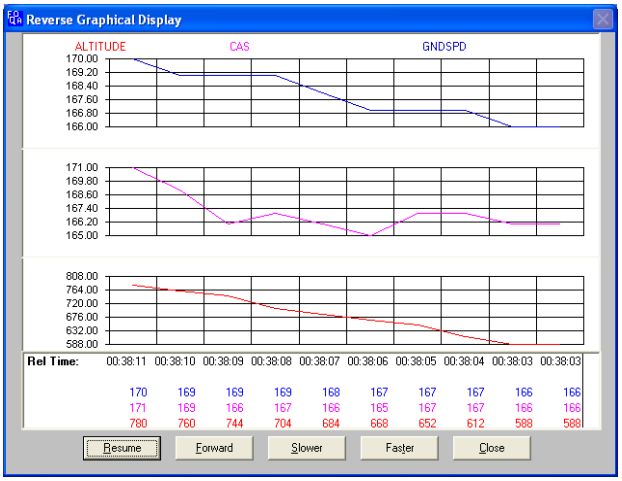


Figure 6 Typical Event Report used for incident analysis

Once NALFOQA detects the events, the event needs to be thoroughly analyzed before the event is marked for tracking. This is done in many ways, however the software provides graphical and alphanumeric displays for validation of events as shown in Figure 7.



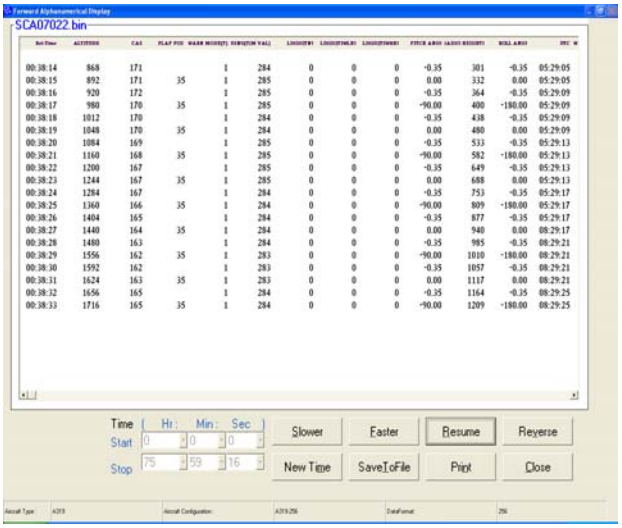


Figure 7 Event analysis graphical and alphanumeric displays of NALFOQA

1.8 Report and statistics management

NALFOQA provides number of statistical and operational reports catering to various levels of requirement from airworthiness to Engineering requirement. Typical Trend Analysis report and Event rate report are as shown in Figure 8 and Figure 9 respectively.

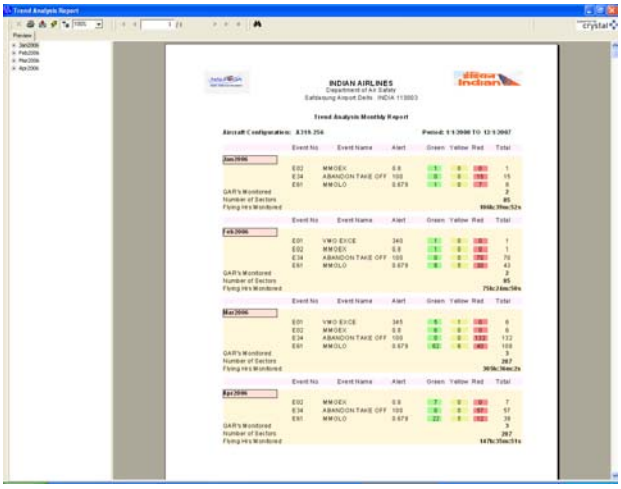


Figure 8 Monthly trend analysis report of NALFOQA

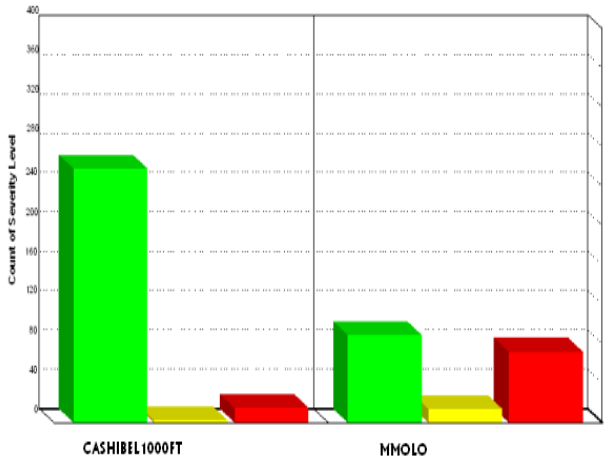


Figure 9 Event Rate report of NALFOQA

Similarly the reports module of NALFOQA has the following major reports apart from other routine analysis reports

- Event rate report
- Trend rate report
- Trend analysis report
- Counseling Report
- Daily, monthly, quarterly, half yearly and yearly report

Each of the analysis and the resulting Report are being exhaustively used at various airlines for operations and incident/accident analysis point of view. Benchmark figure of NALFOQA for 200 hours of flight data is less than 90 seconds for complete analysis.

Results of all reports and data analyzed are validated against the FDAU specifications for SARAS [6].

Conclusion and Future work

NAL Flight Operations Quality Assurance software tools has been successfully used in major airlines like Indian Airlines, Air India, Alliance Air etc,. for their day to day Flight Data Recorder (FDR) data analysis as per DGCA mandate. Use of the tool has enabled airlines for reduced insurance premiums. This is one of the greatest achievements of the NALFOQA tool in the civil aviation industry.

Integration of 3D animation tools along with Terrain databases of all major airports in India, Network version of existing software, is a part of Future work, which is going on at NAL.

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